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LINE REFURBISHMENT PROGRAM

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A program for long term planning for transmission line refurbishment was initiated. This report summarizes the tests, and their results to date, for the portion of the program covering the conductors, insulators and line hardware. Recommendations are given for improving the usefulness of the data obtained and the manner in which conductor samples are selected.

INTRODUCTION

A significant proportion of the transmission lines in Ontario Hydro are approaching or are older than the 50 year design life of the conductors and other line components. Because the refurbishing or rebuilding these lines will be a major undertaking, a program for long term planning for transmission line refurbishment was initiated/1,2/. This report summarizes the tests, and their results to date, for the portion of the program covering the conductors, insulators and line hardware. Separate studies for the towers and their foundations are being conducted by others.

The objectives of this portion of the program include getting some initial data regarding the present condition and rate of aging of older conductors, insulators and line hardware. If the data indicates it to be appropriate, the design life of conductors and other line components might be revised accordingly. In addition, evaluation and refining of the sampling and testing methods for conductors, overhead ground wires, sleeves and deadends, insulators, clamps, hangers and other line hardware is to be included. The data obtained and the methods developed are to be used in future investigations and activities designed to assess the current condition and predict the rate of deterioration of these items. When combined with other data this should ultimately lead to development of policies for determining and scheduling refurbishment/replacement activities.

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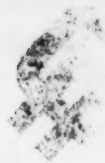

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TESTING

Before testing, all samples were inspected, looking for corrosion, wear, loss of galvanizing, or any mechanical or electrical damage. Some samples were culled at this point, if the inspection and testing of other similar samples left no doubt that they were in 'as new' condition. Any doubtful items were then subjected to the appropriate tests.

Overhead ground wires were tested for strength using tension tests on the individual wires and for loss of ductility (corrosion) using the torsion test, both of which have been used for many years on the 'skywire replacement program'/3/.

Conductors were treated in a similar fashion to that of the overhead ground wires, with additional tensile testing of the aluminum wires which can lose strength from annealing and both strength and ductility from corrosion. Because of the tendency for water, pollutants and corrosion products to migrate down towards the middle of the span, corrosion is usually more prevalent there. For this reason, this portion of the conductors was normally tested for strength loss. Similarly, the conductor samples obtained from under the suspension clamps were examined for signs of wear or fatigue.

After inspection and testing by the Electrical Research Department, insulators were subjected to the combined mechanical and electrical strength test of American National Standard C29.1. When available, the manufacturer and year of manufacture were recorded. This data could potentially be used to indicate relative service life of the various types and makes and the replacement intervals.

Conductor and insulator hardware were classified as to the extent of zinc coating remaining and inspected for wear or other damage. Any item which was damaged, in a manner which might diminish its load capacity, was load tested under simulated service conditions.

Those few conductor compression splice connectors which were received, were submitted to the Electrical Research Department for testing. Any splice which has deteriorated to the extent that it has a discernible strength loss will run hotter and this will be evident from the electrical tests.

RESULTS

A summary of the conductor test results is included in Table 1. Table 2 explains the codes which are used in Table 1 and gives typical examples. Detailed test results are given in the individual test reports which are referred to in Table 1. Additional test reports will be issued and the table will be updated as the testing of conductors continues. Test results for insulators and hardware are summarized in Table 3. Detailed test results are contained in the test report referred to in Table 3.

The following observations were made based on the limited data which has been obtained to date. As the sampling and testing is extended, other conclusions may be drawn.

Conductors:

A variety of causes were observed for those conductor samples which were weakened. They included corrosion of the steel and aluminum wires, annealing or fatiguing of the aluminum wires, and lighting or arcing damage. By far the most common damage was corrosion of the steel core wires which represent about 50 present of the strength for ACSR conductors. Corrosion was most evident at the mid-span where contaminants tended to collect /4/. The data base from the skywire testing program could be invaluable for understanding and predicting corrosion of the steel core wires.

Insulators:

Following the testing of circuit S1K, which was sampled extensively, it became apparent that conductors would be the key concern and the representative from Transmission Lines Programs requested that, unless requested, no further testing of insulators was to be performed. Because only very limited testing was performed, no conclusive findings are possible. The relatively good condition of the conductors and hardware on this circuit suggest that the insulators on this line may not be indicative of the condition of insulators on other lines.

Hardware:

As is evident in Table 3, many items had lost their zinc coating; however, because of the metal thickness, corrosion would have to continue for many more years before any appreciable loss of strength would be observable. Although some wear was evident in several U-bolts and ball eyes from the S1K and P3S circuits, their remaining strength still exceeded the rated strength of the insulators.

Overhead Ground Wires:

Because arrangements have been made to incorporate the skywire program data, those few overhead ground wires which were submitted were tested and reported as part of that program.

SAMPLES

Circuit S1K was the first to become available for testing and was sampled extensively, including conductors, overhead ground wires, sleeves and deadends, suspension clamps, insulators and hangers. A separate investigation of a conductor failure on the D7G circuit in Guelph was then added to this program when it became apparent that conductors would be the primary concern. Other conductor samples, with a minimum age of 40 or 50 years, were then sought. Overhead ground wires, insulators and hardware are regularly inspected and replaced as necessary and were thus deemed to be of little concern. In the tests, only the conductors showed appreciable strength loss and unlike the other items, they require major outages for replacement.

A decision was then made to concentrate on conductors and, as of Nov. 22, 1988, only conductor samples with in-service dates prior to 1940 were solicited. Newer conductor samples running through areas known to have a high level of contamination were also sought. The hardware, if worn, and insulators, if visibly contaminated, were also requested.

Because they have a pronounced sag and are easier to sample, jumper loops are being considered as alternatives for sampling the conductors. Conductor samples will continue to be necessary until we establish what, if any, correlation exists between the degradation of the conductors and jumper loops.

DISCUSSION

Throughout the testing, it was evident that the condition of a conductor varied not only with age, the level of pollution, mechanically and electrically induced damage, etc. but also with the position both along and within the conductor. Complicating the problem even further is the fact that the older conductors appear to have been manufactured with even wider variances in their original strength and galvanizing thickness than we currently demand. Within many line sections and even within some spans, it is quite possible to obtain samples which would vary from an "as new" to a severely degraded condition. All of the preceding emphasize the importance of the selection of the sample and knowing how the submitted sample compares with the rest of the conductor in the line. Several techniques are available for determining the location from which a sample is to be obtained. These include visual observations by the line crew, consideration of local and general environment (pollution, storms, etc.), selection of the portion(s) of the sample to test and the use of the Cormon conductor corrosion meter. Further study will be required to coordinate the use of these methods to obtain a correct assessment and understanding of the condition of any given line.

Because both the conductor condition and its operating environment are continually changing, and often in an unpredictable manner, a monitoring program similar to that used for overhead ground wires should be initiated. As with overhead ground wires, we should attempt to identify weakened conductors when they are still strong enough to be used to pull in the new conductor.

CONCLUSIONS

1. Following extensive testing on one circuit and limited, principally conductor tests on others, the conclusion was reached that conductors would be the primary concern.

2. Conductors with in-service dates prior to 1940 and from known high contamination areas are being tested.

3. Initial results indicate that age is only one of many factors affecting the life of conductors. There is not sufficient data as yet to predict their relative importance and quantitative effects.

4. Corrosion of the steel core wires is the most common cause of loss of conductor strength.

RECOMMENDATIONS

1. A systematic and ongoing program similar to the skywire program should be initiated for conductors.

2. The data base from the skywire program should be utilized to predict trouble areas for conductors and the remaining life of corroded conductors.

3. Further testing and studies should be performed to ensure that the samples selected for testing give a true and complete assessment of the remainder of the conductor on the sampled line circuit and section.

ACKNOWLEDGMENT

All of the conductor and most of the other tests were performed by Mr. G.A. Subject. His testing knowledge and many years of experience in assessing conductors and line hardware have provided accurate, consistent and repeatable evaluation of the conductors and hardware.

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REFERENCES

1. "Long Term Planning For Transmission Line Refurbishment", Task Group Report Part 1.

2. "Long Term Planning For Transmission Line Refurbishment", Task Group Report Part 2.

3. "Evaluation of Service Life of Galvanized Steel Skywire", E.A. Grzybowski, O.H. Report # 79-289.

4. "Conductor: Shiningtree TS - Blezard Valley Jct.", G.A. Subject, O.H. Report # BH89-18.

TABLE 1

Summary of Conductor Test Results

Date Mo/Year	Circuit / Section Junctions	I. S. D. Mo/Year	Conductor size	Conductor const.	Conductor type	Steel Galv.	Steel Duct.	Alum.	% RTS	Code	Tower No.	Report No.	Remarks
2 / 88	S1K / Q96X39 Elgin Jct - Battersea DS	11 / 28	477	26 / 7	ACSR	R1	D10	AN	88	RT10	150,153	BH89-24	
3 / 88	Q3K / Q3X63 Frontenac TS - Westbrook Jct	10 / 40	477	26 / 7	ACSR	R3	D5	AN		RT5	72	BH89-19	
3 / 88	C28C / NA2X81 Chats Falls - Cherrywood TS	10 / 28,31	795	54 / 7	ACSR	R1	D10	AN		RT10	414	BH89-23	
3 / 88	P3S / Q12X65 Sidney TS - Dale Jct	8 / 28	477	26 / 7	ACSR	R2	D10	AN		RT10	17,58,59	BH89-22	
3 / 88	S1K / QA2X62 SmithFalls TS - Forfar Jct	11 / 28	477	26 / 7	ACSR	R2	D10	AN		RT10	14	BH89-21	
6 / 88	D7G / NW5X51 Cedar TS - CGE Jct	3 / 42	266.8	6 / 7	ACSR	R3	D5	C1	49	RP	9 - 10	B88-33	broken wires
"	D7G / NW5X51 Cedar TS - CGE Jct	3 / 42	266.8	6 / 7	ACSR	R1	D5	C1	57	RP	9 - 10	"	arcing damage
"	D7G / NW51X67 CGE Jct - Speedsville Jct	1910	266.8	6 / 7	ACSR	R4	D0	C2	71	RP	79 - 80	"	heavy lime deposit
"	D7G / NW51X67 CGE Jct - Speedsville Jct	1910	266.8	6 / 7	ACSR	R4	D0	C2	81	RP	82 - 83	"	broken wire
"	D7G / NW51X67 CGE Jct - Speedsville Jct	1910	266.8	6 / 7	ACSR	R4	D5	C2	50	RP	90 - 91	"	arcing damage
"	D9G / NW5X51 Cedar TS - CGE Jct		336.4	30 / 7	ACSR	R4	D5	C3	62	RP	10 - 11	"	heavy lime deposit
"	B5G Cedar TS - ?		336.4	30 / 7	ACSR	R3	D5	C2	97	RT5	226 - 227	"	heavy lime deposit
"	B5G Cedar TS - ?		336.4	30 / 7	ACSR	R3	D5	C2	67	RP	226 - 227	"	heavy lime deposit arcing damage
"	B5G Cedar TS - ?		336.4	30 / 7	ACSR	R3	D5	C2	69	RP	226 - 227	"	heavy lime deposit arcing damage
"	B5G Cedar TS - ?		336.4	30 / 7	ACSR	R3	D5	C2	80	RP	226 - 227	"	heavy lime deposit
"	B5G Cedar TS - ?		336.4	30 / 7	ACSR	R3	D10	C2	96	RT10	226 - 227	"	heavy lime deposit
"	B5G Cedar TS - ?		336.4	30 / 7	ACSR	R3	D5	C2	82	RT5	226 - 227	"	heavy lime deposit arcing damage
"	29 samples from above				ACSR							"	visually examined
6 / 88	A7L / P57X12 Reserve Jct - Lakehead TS	5 / 27	336.4	30 / 7	ACSR	R1	D10	AN		RT10	326,362,363	BH89-6	
6 / 88	R1LB / P57X12 Reserve Jct - Lakehead TS	9 / 24	4/0	19 str.	Cu					AN	375,419	BH89-14	
6 / 88	B1S / Q38X12 Tweed DS - Sidney TS	7 / 37	336.4	26 / 7	ACSR	R2	D10	AN		RT10	706	BH89-9	
6 / 88	K6Z / NW30X53 Tilbury TS - Belle River Jct	1968	266.8	26 / 7	ACSR	Z	AN	AN	100	AN	227,228	BH89-11	

TABLE 1 (Con't)

Summary of Conductor Test Results

Date Mo/Year	Circuit / Section Junctions	I. S. D. Mo/Year	Conductor size	Conductor const.	Conductor type	Steel Galv.	Steel Duct.	Alum.	% RTS	Code	Tower No.	Report No.	Remarks
7 / 88	S2S / G51X15 Meaford TS - Owen Sound TS	7 / 47	477	26 / 7	ACSR	R1	D10	AN		R10	532	BH89-16	
7 / 88	T1B / NQF3401XFS69 Striker DS - Cobden Jct	1971,1981	477	26 / 7	ACSR	Z	AN	AN		AN	299	BH89-3	
7 / 88	B4B / FS19X26 Blind River TS / Algoma TS	7 / 50	477	26 / 7	ACSR	Z	AN	AN		AN	444	BH89-3	
8 / 88	56M1 / P56X33 Nipigon Jct - Red Rock DS	5 / 21	266.8	6 / 7	ACSR	R4	D0	AN	75	RP	234,235	BH89-7	
8 / 88	T1M / P15X77 Marathon TS - Terrace Bay SS	10 / 55	477	26 / 7	ACSR	Z	AN	AN		AN	289,290	BH89-12	
8 / 88	56M1 / P33X18 Redrock DS - Domtar Ltd.	9 / 37	4/0	6 / 1	ACSR	R2	D10	AN		RT10	268,269	BH89-15	
9 / 88	K4G / FA16X89 KirklandLake TS-MatachewanJ	4 / 34	2/0	7 str.	Cu					AN	22	BH89-5	
9 / 88	K2R / FA16X64-02 Kirkland lake TS - Arjon Jct	1927	4/0	7 str.	Cu					AN	106	BH89-5	
9 / 88	L2T / FT8X7 HerridgeLake DS-CrystalFallsGS	12 / 47	3/0	6 / 1	ACSR	Z	AN	AN		AN	315	BH89-8	
9 / 88	H23S / FL7X9 CrystalFallsGS-RHMartindaleGS	3 / 53	477	26 / 7	ACSR	Z	AN	AN		AN	77	BH89-8	
9 / 88	W7W / NW38X19 Ingersol TS - EVBuchanan TS	12 / 10	336.4	30 / 7	ACSR	R1	D10	AN		RT10	290	BH89-20	
10 / 88	S2B / FS72X93 Turbine Jct - Drury Jct	7 / 50	477	26 / 7	ACSR	R1	D10	AN		RT10	1151	BH89-4	
10 / 88	T2R / FA25X70 ShiningtreeTS-BlezardValleyJct	9 / 31	336.4	30 / 7	ACSR	R3	D5	AN	100	RT5	914	BH89-18	
12 / 88	M2K / FA18X16-02 Ramore TS - Kirkland Lake TS	1 / 34	2/0	7 str.	Cu					AN	427	BH89-2	
12 / 88	Idle / NT60X13 Halton Jct - Cooksville TS"B"	3 / 11	312	30 / 7	ACSR	R3-R4	D0	AN	89	RP	17 - 19	BH89-13	
12 / 88	T1M / P77X82 ?	10 / 55	477	26 /7	ACSR	Z	AN	AN		AN	24,76	BH89-17	
12 / 88	P5M / 2X66 PortArthur TS #1 - Conmee Jct	11 / 43	312	30 / 7	ACSR	R3-R4	D0	AN	91	RP	157,158	BH89-10	reused conductor = 80 years old

TABLE 2

CONDUCTOR SUMMARY SHEET CODES

Column	Code	Description	Example
Galv.	Z	zinc coated	
	R1	rusted, no rust pitting	
	R2	rusted, minor rust pitting	
	R3	rusted, moderate rust pitting	
	R4	rusted, severe rust pitting	
Duct.	AN	as new	zinc covered, no rust, ≥ 20 turns
	D10	recommend 10 yr retest	some rust, 10-20 turns
	D5	recommend 5 yr retest	some rust and pitting, 5-10 turns
	D0	consider replacement	severe pitting, ≤ 4 turns
Alum.	C1	minor corrosion	
	C2	moderate corrosion	
	C3	severe corrosion	
	AN	as new	aluminum wires full strength
	A75	moderate annealing	aluminum wires ≈ 75% strength
	A50	severe annealing	aluminum wires ≤ 50% strength
Code	AN	as new	zinc covered, no strength loss
	RT10	recommend 10 yr retest	minor corrosion and ductility loss
	RT5	recommend 5 yr retest	moderate corrosion and ductility loss
	RP	consider replacement	strength and ductility loss

TABLE 3

SUMMARY OF INSULATOR AND HARDWARE TEST RESULTS

DATE MON/YR	CIRCUIT/SECTION JUNCTIONS	ISD. MON/YR	STRUCT NO.	INSULATORS REMARKS	INSULATORS NO.	INSULATORS CONDITION	SUSPENSION CLAMP REMARKS	SUSPENSION CLAMP CONDITION	TOWER "U" BOLTS STOCK DIA. (IN)	TOWER "U" BOLTS CONDITION
JUNE/88	K6Z/NW30 x 53 TILBURY TS TO BELLE RIVER JCT	AUG/1914	227/228	ORIGINAL	24	CAPS RUSTED	ORIGINAL	RUSTED	5/8	APPROX 15% OF DIA WORN AWAY
JUNE/88	B1S/Q38 x 12 TWEED DS (LODGEROOM) TO SIDNEY TS	JULY/1937	706	ORIGINAL	4	CAPS PARTIALLY TO FULLY RUSTED	-	-	-	-
DEC/88	M2K/FA18 x 16-02 RAMORE TS TO KIRKLAND LAKE TS	JAN/1934	427	ORIGINAL	7	-	ORIGINAL	GOOD COND	-	GOOD CONDITION
SEPT/88	K4G/FA16 x 89 KIRKLAND LAKE TS TO MATCHEWAN JCT	APR/1934	22	REPLACE	8	GOOD COND.	ORIGINAL	RUSTED GOOD COND	-	RUSTED GOOD COND - NO WEAR
SEPT/88	K2R/FA16 x 64-02 KIRKLAND LAKE TS TO ARJON JCT	1927	106	MIXED-MAJORITY REPLACE	24	GOOD COND.	-	-	1/2	GOOD COND - NO WEAR
OCT/88	J2R/FA25 x 70 SHININGTREE TS TO BLEZARD VALLEY JCT	SEPT/1931	914	ORIGINAL	21	-	ORIGINAL	PARTIALLY RUSTED GOOD COND	5/8	RUSTED APPROX 30% OF DIA WORN AWAY (BALL/EYE RUSTED - APPROX 20% OF DIA WORN AWAY)

TABLE 3 (Con't)

SUMMARY OF INSULATOR AND HARDWARE TEST RESULTS

DATE MON/YR	CIRCUIT/SECTION JUNCTIONS	ISD. MON/YR	STRUCT NO.	INSULATORS			SUSPENSION CLAMP		TOWER "U" BOLTS	
				REMARKS	NO.	CONDITION	REMARKS	CONDITION	STOCK DIA. (IN)	CONDITION
OCT/88	S2B/FS72 x 93 TURBINE JCT TO DRURY JCT	JULY/1950	1151	ORIGINAL	7	CAPS PARTIALLY TO FULLY RUSTED	ORIGINAL	RUSTED	1/2	SLIGHTLY WORN
JULY/88	B4B/FS19 x 26 BLIND RIVER TS TO ALGOMA TS	JULY/1950	444	-	18	-	-	-	1/2	SLIGHTLY WORN
JULY/88	T1B/NQF3401xFS69 STRIKER DS TO COBDEN JCT	APR/1971 NOV/1981	299	ORIGINAL 1950?	7	CLEAN	-	VERY CLEAN	1/2	AS NEW
SEPT/88	L2J/FT8 x 7 HERRIDGE LAKE DS TO CRYSTAL FALLS GS	DEC/1947	315	ORIGINAL	8	-	-	GOOD COND. - PART LOSS OF TORQUE ON FASTENERS	-	APPROX 25% OF DIA WORN AWAY LESS WEAR ON BALL/EYE FITTING

NOTE: FOR DETAILED TEST RESULTS SEE O.H. REPORT NO. B89-8-K